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Utility of Helicopter Rotor Reflections at HF

[Unclassified Title]

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ABSTRACT

([redacted]) Recent over-the-horizon (OTH) surveillance exercises conducted by the Naval Research Laboratory in cooperation with air and surface units of the U.S. Fleet have permitted the opportunity for detection and characterization of the rotor modulations of the SH-3D helicopter.

([redacted]) The uniqueness of the radar signature of the SH-3D rotor blade affords adequate discrimination in an environment of multiple conventional aircraft. Such echoes have been obtained from the SH-3D at line-of-sight ranges and at approximately 870 and 2070 naut mi from the radar.

([redacted]) Though no extensive detection statistic has yet been accumulated, use of a ship's own helicopter for locating the ship's position within the OTH-sensor envelope has been tentatively demonstrated, as disclosed in this report.

AUTHORIZATION

NRL Problem R02-23
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UTILITY OF HELICOPTER ROTOR REFLECTIONS AT HF

[Unclassified Title]

INTRODUCTION

(S) During the past decade, the Naval Research Laboratory has been active in the development of over-the-horizon (OTH) radar techniques that have permitted the detection and tracking of aircraft (1), missiles, and ships. In the recent past, NRL has been engaged in surveillance exercises conducted in cooperation with surface and air units of the U.S. Fleet (2), and these exercises have demonstrated the utility of OTH sensing in the relief of the fleet-air-defense problem imposed on quiet task forces.

(S) The correct positions of the surface units are of paramount importance in correctly interpretating the remote air picture. The detection of the radar echo from the ship or ships, enhanced by the increase in ship's speed as well as by the increase in radar emission bandwidth, is often achieved. Disturbed ionospheric conditions, however, make the direct detection of the ship difficult and require another technique for ship location. Selectively responsive beacons have been used aboard ship for the purposes of identification and location (3).* Such transponders may prove incompatible with an emission-control (EMCON)-constrained environment. Testing of the degree of compatibility is indicated for the near future.

(S) The use of a ship's helicopter is another technique for the location of a surface group, which is compatible with EMCON and does not require modifications in radar emission bandwidth and which is relatively independent of diurnal variations as well as moderate disturbances in the ionosphere. Because the helicopter possesses a characteristic radar signature due to its rotor-blade echoing behavior, it should be uniquely identifiable at remote OTH ranges. If the helicopter were deployed at regular intervals of 6 hr for 15 min, within approximately 15 naut mi of the ship, and flown at altitudes below 500 ft to preclude betrayal of position to hostile forces, such flight could flag the approximate position of the host ship to the OTH sensor.

(U) The SH-3D helicopter has been in use for several years on CVS carriers such as the *U.S.S. Wasp* and *U.S.S. Intrepid*. On these carriers the SH-3D performs as ASW function. Recently the CVA carriers embarked the SH-3D.

SUMMARY

(S) This report presents detection results for observations of the SH-3D helicopter at line-of-sight (LOS) ranges (out to 90 naut mi) and at OTH ranges of 870 and 2070 naut mi. An assessment of LOS and OTH radar cross sections is given. The relative echoing

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*Personal communication with Dr. James Barnum of the Stanford Research Institute, Menlo Park, California.

[redacted]

strength of the main-rotor modulations is discussed. The required signal-to-noise ratio (S/N) for main-rotor first-and-second-order sideband discernibility is discussed.

(U) The appendix contains a listing gleaned from *Jane's Fighting Ships 1971-72* (4) showing the current and pending widespread use of helicopters in the fleet.

DESCRIPTION OF THE SH-3D HELICOPTER

(U) The model SH-3D helicopter (5) is manufactured by Sikorsky Aircraft Division of United Aircraft Corporation, Stratford, Connecticut. The helicopter is designed principally for both shore and ship-based operations to detect, identify, track, and/or destroy enemy submarines during round-the-clock operations. The crew consists of pilot, copilot, and two sonar operators. The airframe configuration is that of a single-rotary-wing, twin-turbine-powered helicopter with emergency amphibious capabilities (Figs. 1 and 2).

(U) Fig. 1—SH-3D helicopter on the ground at Patuxent River Naval Air Station

(U) The physical dimensions of the airframe are detailed in Fig. 3. As indicated, the rotary-wing blades and rotary rudder are collapsible for facilitating shipboard storage. The SH-3D is deployed in the fleet aboard attack and ASW aircraft carriers.

(U) The helicopter is capable of airspeeds up to 144 knots. Endurance will vary between 3.5 and 5.5 hr, depending on hover time. Fuel consumption is approximately 1200 lb/hr while hovering and 1000 lb/hr when cruising. Total fuel load is 4,746 lb. Total airframe weight when loaded is approximately 17,000 lb.

(U) Fig. 2—SH-3D helicopter in hover pattern dipping ASW sonobuoy

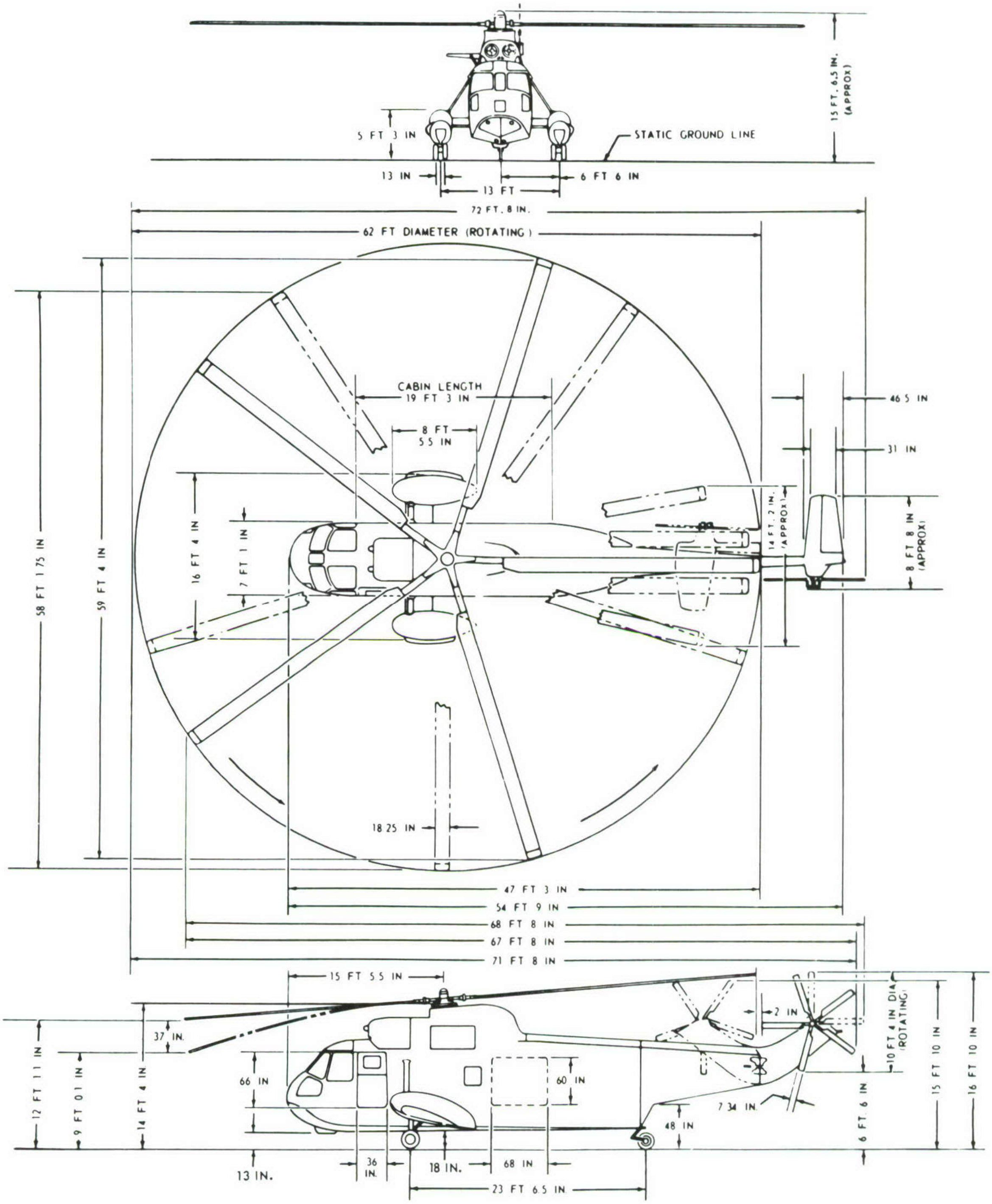
EXPERIMENTAL OBSERVATIONS

Line-of-Sight Detection Results

([redacted]) In May of 1970, NRL requested the Patuxent River Naval Air Station to fly an SH-3D in the view of the MADRE radar at the Chesapeake Bay Division of NRL (NRL/CBD) in order that a reference line-of-sight measurement might be made of radar cross sections of the fuselage and rotor blades. A description of the doppler behavior of the blade echo was also obtained; this description is discussed later.

([redacted]) The SH-3D was flown at an altitude of 9,500 ft from NRL/CBD on a bearing of 71°T to Sea Isle City, N.J.; the return flight was over the same path at an altitude of 10,500 ft. Even though the flight was conducted in an area of moderately high aircraft density, detection of the fuselage and first-order main-rotor echoes was achieved from approximately 20 naut mi in range to the position over Sea Isle City on outbound and inbound flights. The helicopter flight path traversed vertical angles at the radar of from 5° to less than 1°. This permitted adequate illumination with the MADRE phased-array antenna.

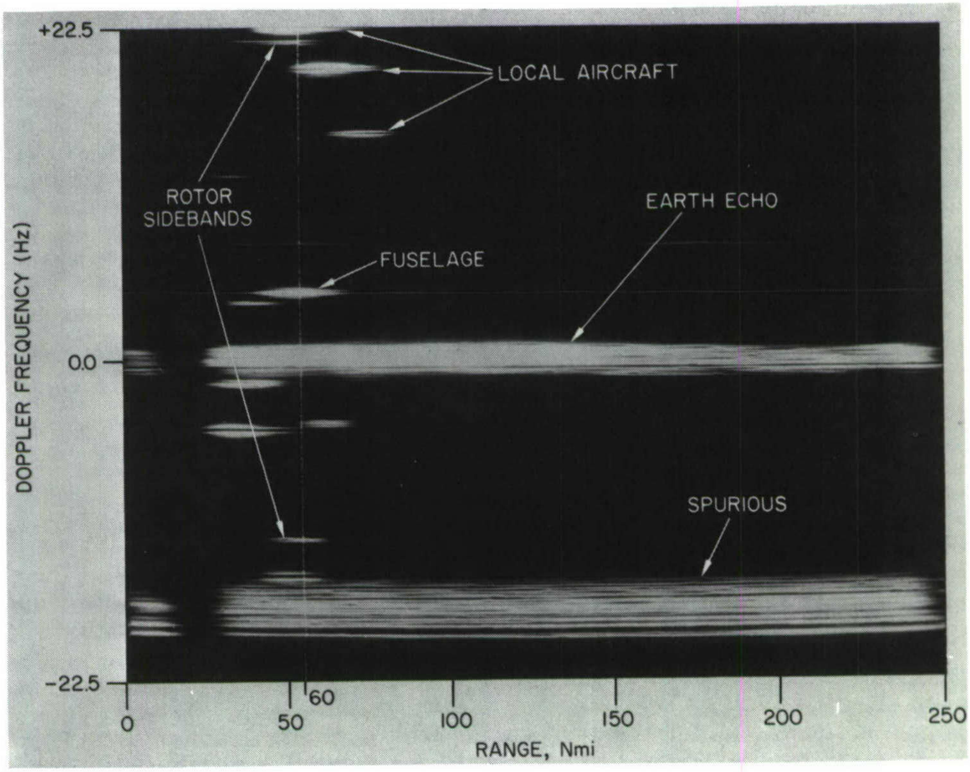
([redacted]) Operation was at a frequency of 15.532 MHz at a 2.3-MW level and a 90-Hz pulse-repetition frequency. Coherent processing was set up in an offset mode, with 22.5 Hz being used as the offset frequency. This choice partitioned the 45-Hz available doppler range into two sections, one for approach targets and one for recede targets, up to a maximum unambiguous doppler of 22.5 Hz for each section. For the anticipated flight velocity, the 22.5-Hz offset would permit both of the first-order components, due to the rotor-blade echoes, to lie within the unambiguous doppler extent.



(U) Fig. 3—Principal structural features of SH-3D with corresponding dimensioning

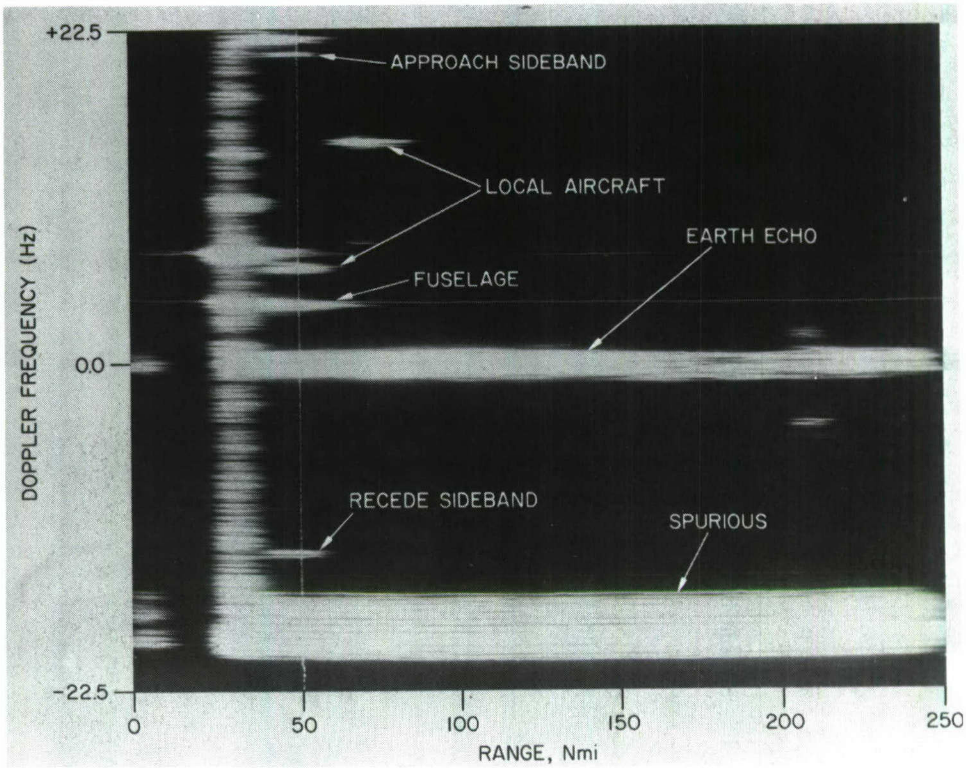
(S) The SH-3D helicopter has five blades on its main rotor as well as on its tail rotor (or rudder rotor). The main rotor turns at an approximate constant speed of 203 rpm. The rudder rotor rotates at 4.92 × 203 rpm, or approximately 1000 rpm. The combination of main-rotor speed and the number of main-rotor blades results in an optimum echoing cross section 16.9 times each second. Thus it is expected that the main-rotor modulations detected would be spaced 16.9 Hz on either side of the helicopter-fuselage echo. For the radar operating frequency and expected speed of 100 knots, the resultant fuselage doppler would be approximately 4.5 Hz, which when added to 16.9 Hz rotor modulation frequency results in a doppler of 21.4 Hz. Both the fuselage and rotor modulation dopplers are within the ±22.5-Hz unambiguous range.

(S) Figure 4 is the doppler-vs-range readout for 1945 GMT. The earth echo and spurious signals are as indicated. Of note is the target which is under the range and doppler strobes and which is the echo from the fuselage of the SH-3D. The helicopter at this time is on its inbound leg to the NRL radar site from Sea Isle City. The targets which are weaker in appearance, almost at the approach and recede doppler display limits, are the corresponding rotor sidebands. The separation between the fuselage and the two sidebands is the nominal 16.9 Hz. Other targets in view are local aircraft.



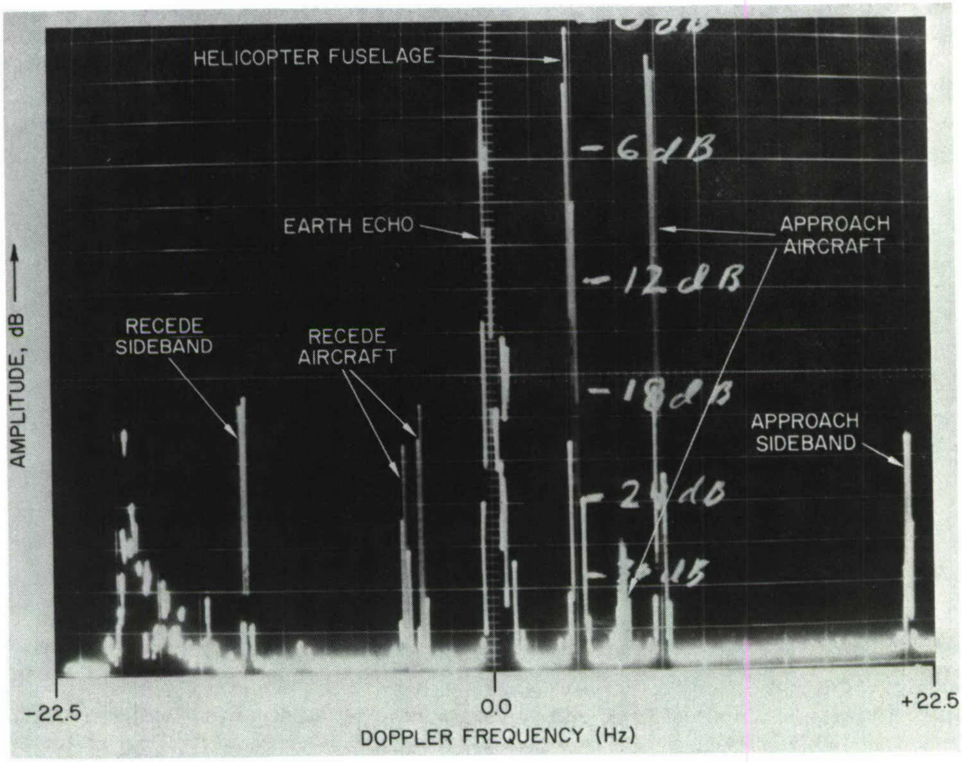
(S) Fig. 4—Doppler-vs-range display for LOS helicopter flight of 7 May 1970. Doppler-frequency offset = 22.5 Hz. Range extent = 250 naut mi. Target range = 60 naut mi at 1945 GMT.

([redacted]) Figure 5 is quite similar to Fig. 4, except for a range change in the helicopter. The helicopter is 10 naut mi nearer than in Fig. 4. The range and doppler strobes intersect the helicopter-fuselage echo. The approach and recede sidebands can again be seen at the upper and lower ends of the range strobe line. As evidenced in Fig. 4, local aircraft are still under illumination.



([redacted]) Fig. 5—Doppler-vs-range display for LOS helicopter flight of 7 May 1970. Doppler-frequency offset = 22.5 Hz. Range extent = 250 naut mi. Target range = 50 naut mi at 1950 GMT.

([redacted]) Figures 6 and 7 are amplitude-vs-doppler readouts that permit a rather fine-grain analysis of the helicopter sidebands, especially their appearance in the doppler field and their relative amplitude in dB. Figure 6 shows the spectral occupants at the approximate range (36 naut mi) of the helicopter for the time 2001 GMT. Centered approximately in the display is the echo due to stationary or near-stationary scattering from the earth's surface as propagated by surface wave and skywave. The various spectral elements in the range sample are as identified. As mentioned earlier, the helicopter traversed rather populous air space. In view in Fig. 6, in addition to the helicopter signature, are four local aircraft, with two on the recede side at −18 dB and two on the approach side, with one at −2 dB and the other at approximately −30 dB. The helicopter fuselage exhibits a 0-dB amplitude which yields an apparent HF cross section of 84 m^2. The first-order rotor-blade modulations are as indicated, with corresponding amplitudes of −20 and −18 dB. Second-order effects, though expected, are not in appearance in this record.



(S) Fig. 6—Amplitude-vs-doppler-frequency spectral readout for LOS helicopter at 2001:00 GMT. The abscissa is doppler frequency in Hz. The ordinate is amplitude in dB, as indicated by the inset scale. Target range = 36 naut mi.

(S) Figure 7, similar to Fig. 6, is also a spectral readout of amplitude in dB vs doppler frequency for the SH-3D helicopter at a range of 33 naut mi at 2003:30 GMT. The earth echo as propagated by surface wave and skywave is seen centered on a doppler frequency of 0.0 Hz. Local aircraft are again identified, with two on the recede side and one on the approach side. The helicopter sidebands are in view at points near the ends of the doppler scales. The fuselage-echo amplitude is approximately at 0 dB. The approach-rotor sideband is at −20 dB, and the recede sideband is at −18 dB.

(S) For the data available at this reporting and that taken for the case of the approaching helicopter, the recede-rotor modulation component generally appears to be, on the average, 3 dB larger than the approach-rotor modulation component. This estimate has been deduced from the data in Table 1.

(S) That the rotor sidebands could show small differences in apparent echoing cross section could be due to phase modulation of the echoing energy, as generated by the interaction of the rotating blade system and the helicopter fuselage.* An area for fruitful theoretical investigation seems indicated. With a proper understanding of the echoing mechanism for radar energy scattered from a helicopter, it is likely that signatures detected could yield helicopter identification.

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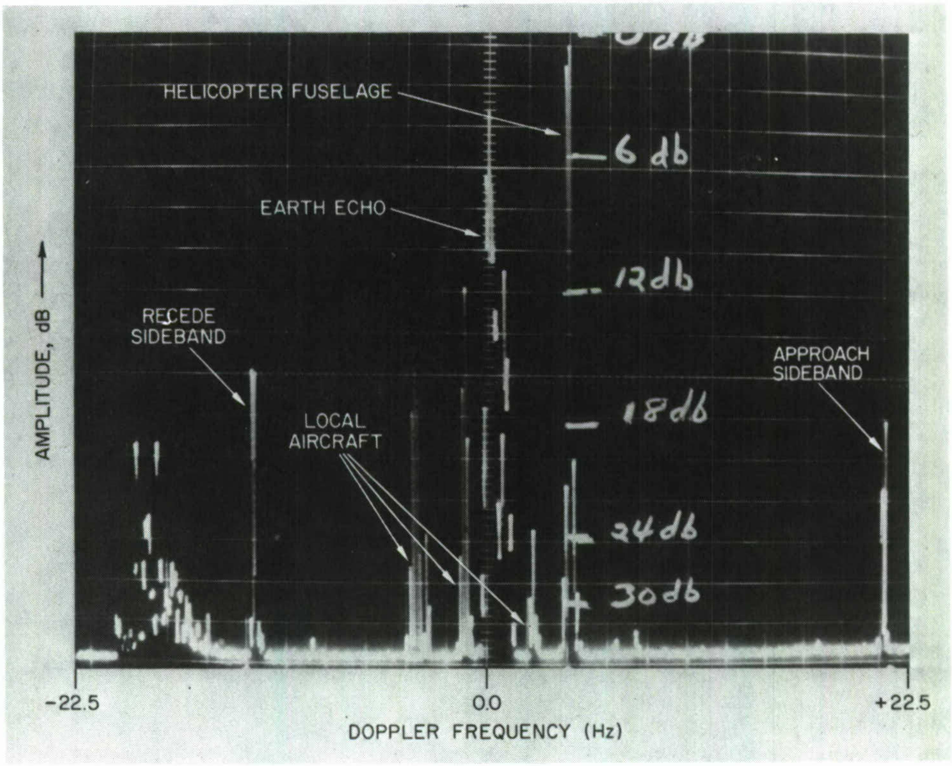
*Personal communication with Dr. Lewis Wetzel at NRL.



([redacted]) Fig. 7—Amplitude-vs-doppler-frequency spectral readout for LOS helicopter at 2003:30 GMT. The abscissa is doppler frequency in Hz. The ordinate is amplitude in dB, as indicated by the inset scale. Target range = 33 naut mi.

([redacted]) Table 1
Rotor Modulation Amplitudes for LOS SH-3D Helicopter Target

Time (GMT)	Range (naut mi)	Fuselage Doppler (Hz)	Recede Doppler (Hz)	Component Amplitude* (dB)	Approach Doppler (Hz)	Component Amplitude* (dB)	Recede Approach (dB)
1956:00	40	26.3	9.3	−15	43.3	−20	5
1958:30	37	26.3	9.3	−14	43.3	−17	3
2001:00	36	26.4	9.4	−18	43.3	−21	3
2003:30	33	26.5	9.5	−16	43.4	−18	2
2007:00	29	26.9	9.9	−14	43.8	−18	4
2008:43	27	26.3	9.3	−18	43.3	−21	3

*Rotor modulation components are referenced to the fuselage echo (0-dB level).

([redacted]) The experimental results listed in Table 1 indicate that the difference in cross section for the two blades varied from sample to sample over the amplitude range of 2 dB to 5 dB, with the average being slightly greater than 3 dB. Such differences can be readily explained on the basis of relatively small indices of phase modulation.

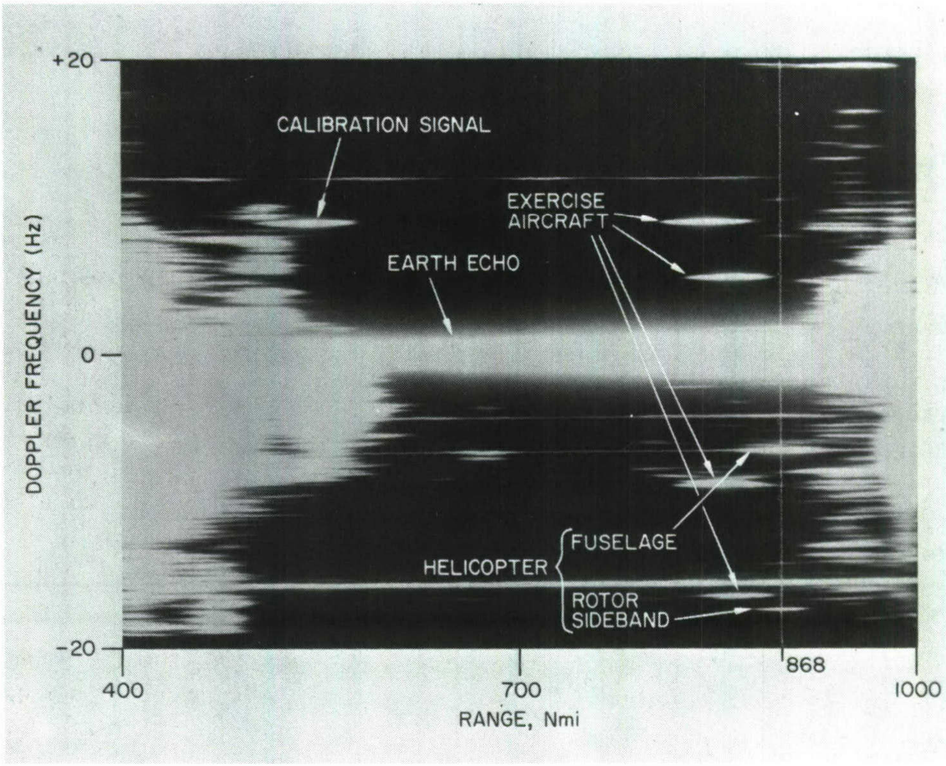
Over-the-Horizon Detection Results

([redacted]) *U.S.S. Wasp* Surveillance Exercise of 14 May 1970 (2)

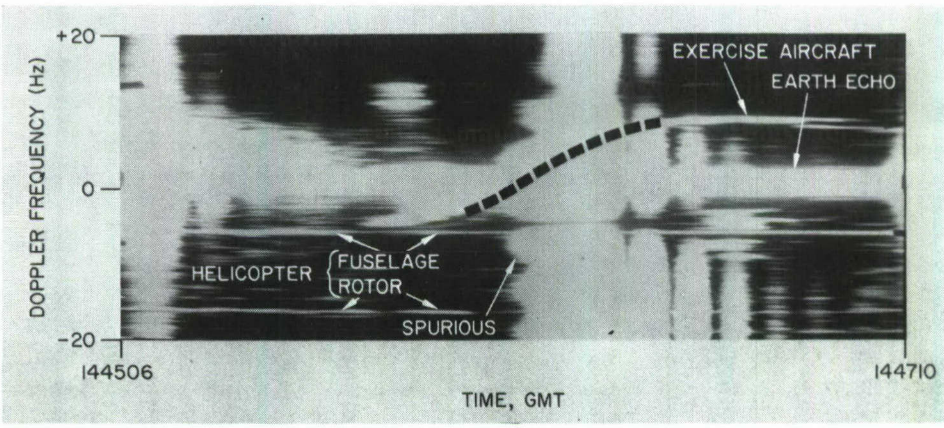
([redacted]) The MADRE radar was deployed on this occasion to determine the feasibility of OTH sensing for the purpose of fleet air defense. For the purposes of this exercise, the *U.S.S. Wasp* HUK group was separated into two smaller groups 70 naut mi apart, each group consisting of three destroyers, with the *U.S.S. Wasp* attached to one of these. Multiple mock raids were detected as implemented with *U.S.S. Wasp* aircraft on flights between the two ship groups. Position reports for the raiding aircraft were passed in real time to the ship under impending "attack." An SH-3D helicopter was used during the exercise to flag the position of the three-destroyer group in the event that this group would not be directly detected. As it materialized, both ship groups engaged in the exercise were held in continuous detection. The helicopter was also detected and tracked in transit between the two ship groups.

([redacted]) The next two figures show the detection results for the SH-3D flight activity during the *U.S.S. Wasp* surveillance exercise. Figure 8 is a doppler-vs-range record with 20-Hz offset, 10-s integration, taken at 1453:10 GMT. The range extent is from 400 to 1000 naut mi. The total doppler extent is 40 Hz (for an 80-pps pulse rate), which is divided into two sections, one 20 Hz above the radar operating frequency and the other from the carrier to 20 Hz below the radar operating frequency. The band of signal energy centered on 0.0-Hz doppler is due to the earth echo. Wider doppler signal structures out to 600 naut mi and from approximately 900 to 1000 naut mi are due primarily to transitory meteor echoes. Of particular note is the video signal at the intersection of the range and doppler strobe (this strobe is the second horizontal line below the earth echo). The signal so marked is the echo from the SH-3D helicopter fuselage on an outbound flight path between the two ship groups. The recede-rotor component is in view on the range strobe near the bottom of the record. The helicopter at this time is at a range of 868 naut mi. There are two weaker signals on the approach side of the carrier that seem to be centered on the range strobe, the higher of which coincides with the expected position of the approach-rotor sideband. One would be more confident with a better signal-to-noise ratio. There appear to be four other aircraft in the neighborhood of the helicopter, two approaching and two receding.

([redacted]) Figure 9 is a 124-s doppler-vs-time record with the range sample point at 856 naut mi. The record begins at 1445:06 GMT and extends to 1447:10 GMT. The record is offset in doppler by 20 Hz, with approach targets appearing above the earth echo signal (centered on 0.0-Hz doppler) and recede targets in evidence below the earth echo signal. The doppler extent in both directions is 20 Hz. The helicopter seen in Fig. 8 is in view in Fig. 9 as a horizontal line, as indicated. The recede-rotor modulation is as indicated. It can be seen that it continues, in time, parallel to the fuselage line. The doppler-vs-time display is of great benefit in the recognition of helicopter signatures. It permits the discernment of simultaneity in the fading or slight changing of doppler in each of the



([redacted]) Fig. 8—Doppler-vs-range display for *U.S.S. Wasp* exercise of 1453:10 GMT on 14 May 1970. Doppler offset = 20 Hz. Range extent is from 400 to 1000 naut mi. The ordinate is doppler frequency in Hz. Helicopter target range = 868 naut mi.



([redacted]) Fig. 9—Doppler-vs-time display for *U.S.S. Wasp* exercise of 14 May 1970. Range sample is at 856 naut mi. Time is as indicated on the abscissa.

helicopter doppler components, including fuselage and rotor modulations, which may be caused by a change in the helicopter radial velocity or by an alteration in rotor rotation rate.

([redacted]) Also in view in Fig. 9 is an exercise aircraft which alters its course from receding to approaching at the approximate midpoint of the record. The identification is unconfirmed, but it is thought to be the E1B aircraft that monitored the exercise.

([redacted]) *U.S.S. Independence* Surveillance Exercise of September 1971

([redacted]) During September 1971 NRL engaged in surveillance of the *U.S.S. Independence* as she transited to the eastern Atlantic area (EASTLANT). Observations were made during the period 19-24 September. During this passage the *U.S.S. Independence* deployed the SH-3D helicopter as a plane guard during air operations and at other times on a noninterference basis as a target of opportunity for MADRE system detection, tracking, and characterization.

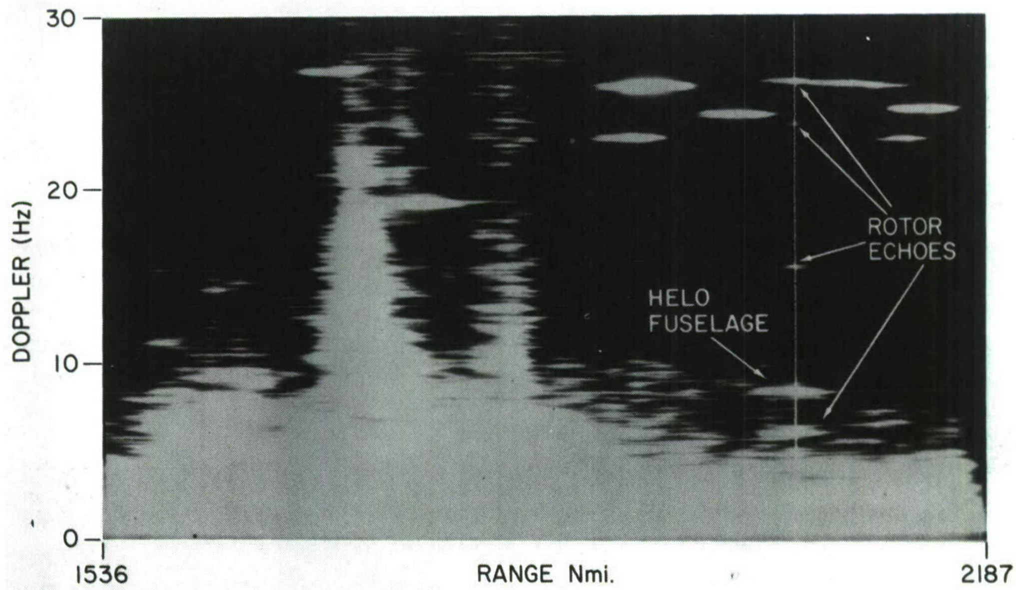
([redacted]) From the analysis that has been completed of the *U.S.S. Independence* surveillance exercise, it has been determined that the SH-3D was detected on several occasions during the six-day exercise. One such detection will be noted here.

([redacted]) Unusually favorable propagation conditions prevailed during the observation period on 23 September. Two-hop geometry permitted the detection of many commercial air carriers over the North Atlantic at ranges in excess of 2000 naut mi. During this observation period the outbound *U.S.S. Independence* penetrated the 2000-naut mi-range contour.

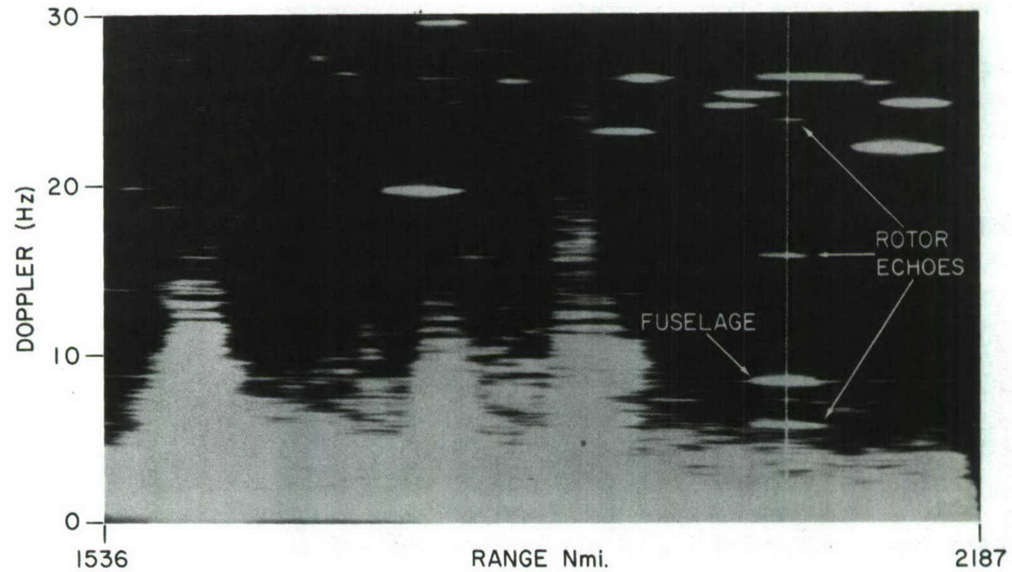
([redacted]) Figure 10 is a doppler-vs-range display for the SH-3D helicopter detection at 2076 naut mi. The echo from the helicopter fuselage and rotor echoes, both first and second order, appear centered on the range strobe. The component below the fuselage is the first-order recede echo due to the rotor-blade echo; the echo in "collision" with an aircraft near the top of the range strobe is the first-order approach component. The two weaker components identified as rotor echoes are second-order responses. The element at approximately 16 Hz is due to the second-order approach echo; the component at 24 Hz is the second-order recede echo. It is obvious from the range coincidence of the multiple scatterers associated with the helicopter that they, together with the fuselage, provide adequate identification and discernibility to permit "flagging" the location of an otherwise undetected surface unit.

([redacted]) Also in view in Fig. 10 are multiple conventional aircraft. Even with the coincidence of a jet-type signature with the first-order approach component, helicopter identification remains unimpaired because of the other rotor echoes.

([redacted]) Figure 11 is similar to Fig. 10, being a doppler-vs-range display for the time 1704:15 GMT. Helicopter components in this record are centered on the range strobe at 2074 naut mi. Three of the rotor components in addition to the fuselage echo still remain visible in spite of masking of the uppermost component by the commercial aircraft. Identity nevertheless remains unique.

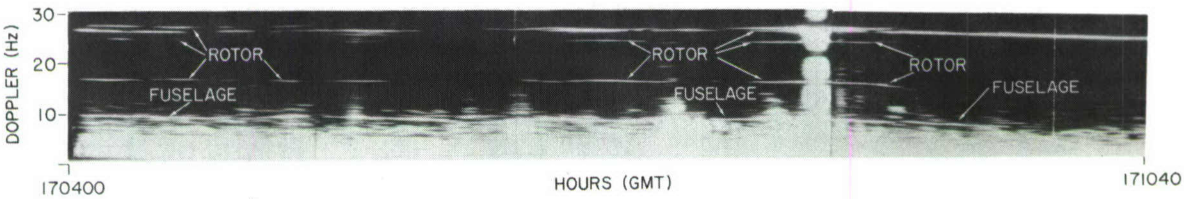


(S) Fig. 10—Doppler-vs-range display at 1703:40 GMT for SH-3D helicopter at a range of 2076 naut mi. Doppler and range extent are as indicated on the ordinate and abscissa.



(S) Fig. 11—Doppler-vs-range display at 1704:15 GMT for SH-3D helicopter at 2074 naut mi. Doppler and range extent are as indicated on the ordinate and abscissa.

(S) Figure 12 is a doppler-vs-time record extending from 1704:00 GMT to 1710:40 GMT. The range sample point is set at 2070 naut mi, the approximate midpoint of travel of the helicopter during the record time frame. The fuselage doppler track (just below 10 Hz) can be seen skirting over the low doppler clutter, which unfortunately masks the first-order recede component. The other components may be seen intermittently through most of the record. Simultaneous fading on the three blade components available is evident.



(S) Fig. 12—Doppler-vs-time record for range-sampled data with the sample at 2070 naut mi. Temporal extent is from 1704:00 to 1710:40 GMT. The doppler extent is as scaled.

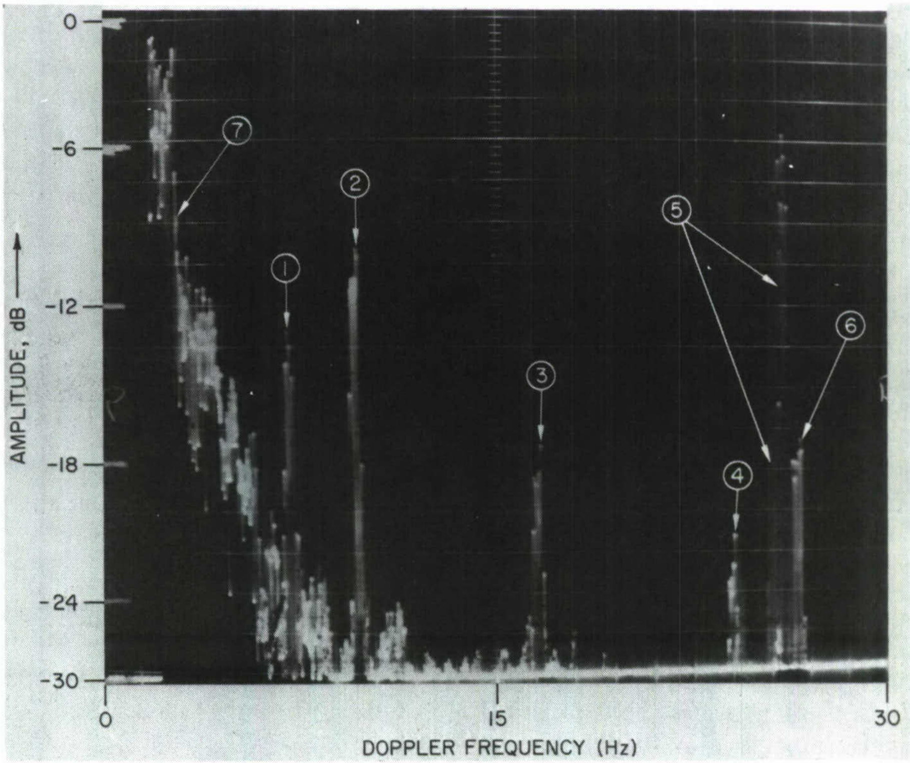
(S) Even though the rotor components suffer a modification in their doppler and then disappear in the neighborhood of 1709 GMT, the fuselage echo persists for 30 or more seconds before disappearing. It is believed this behavior may be related to preparation for landing. On descent the shaft rpm of the SH-3D helicopter may increase up to 223 rpm (10% higher) as a result of unloading the helicopter engines. The slight alteration in rotor components (doppler) prior to their disappearance is in the right sense for an increase in shaft rpm. Their disappearance is likely due to modification in airframe attitude. It was confirmed after the fact that this helicopter did land within a short period of time.

(S) Figure 13 is a spectral readout for a range sample which includes the helicopter and associated rotor sideband frequencies at 1708:30 GMT. The doppler scale is as indicated. The amplitude scale in dB is as indicated in the scale on the left border. The spectral elements are identified by number in the following listing:

Element	Identification
1	First-order recede sideband
2	Helicopter fuselage echo
3	Second-order recede sideband
4	Second-order approach sideband
5	Range-coincident commercial aircraft (2)
6	First-order approach sideband
7	Low-doppler clutter

The 0-dB reference level for Fig. 13 was a 10-μV peak-to-peak calibration signal, which corresponds to a target of 6.84×10^3 m^2 at this range.

(S) Table 2 lists the amplitudes for each of the spectral components of the SH-3D signature during the time interval of the nearly 7-min record of Fig. 12. The blanks in the



(S) Fig. 13—Spectral readout of range-sampled data for the time 1708:30. Range sample centered on SH-3D helicopter at 2061 naut mi. The amplitude is in dB, as indicated on the inset scale on the left. The abscissa is doppler frequency in Hz.

table are times for which the given component was not available due to either obscuration by clutter at the first-order recede frequency or to confusion with the commercial aircraft target at the first-order approach frequency. The second-order approach component, being the weakest component, was on a few occasions below the minimum detectable signal level of the system. During the time period 1706:10 to 1706:40, there seemed to be general outage of rotor modulation components. The fuselage echo during the same time period remained detectable with changing doppler frequency. It is speculated that various helicopter maneuvers might influence the magnitude of the radar cross section of the rotor modulation components, both of the first and second order, with the latter being more sensitive to platform orientation to the incident radar signal.

(S) There also was a scarcity of helicopter-signature components during the time interval 1707:30 to 1707:50. Even though a spectral component was not extracted for the fuselage, the doppler-vs-time record of Fig. 12 indicates it is present but often masked by low-doppler clutter signals. Again it looks as if the rotor modulations have disappeared and the fuselage signal is moderately available. The weak second-order effects are, indeed, very sensitive to general fading. It is conceivable that the fuselage could be detectable without the second-order effects.

(S) For the valid data points of Table 2, estimates have been made of the relative echoing strength of the various spectral elements. Some results are:

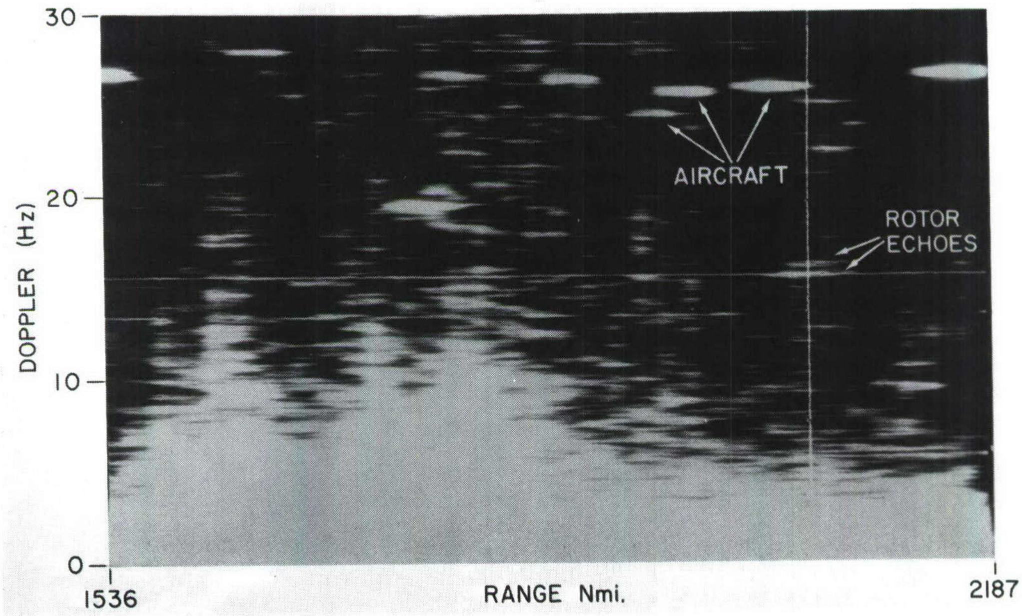
1. Ratio of fuselage echo strength to first-order recede component ≈ +4 dB
2. Ratio of first-order recede echo to first-order approach component ≈ +2 dB
3. Ratio of second-order recede echo to second-order approach component ≈ +4 dB

([redacted]) Table 2
Amplitude of Various Components of the SH-3D Radar Signature as a Function of Time. A Calibration Signal of 10 μV Peak to Peak is the 0-dB Reference
(Unclassified Title)

Time (GMT)	First-Order Recede (dB)	Fuselage (dB)	Second-Order Recede (dB)	Second-Order Approach (dB)	First-Order Approach (dB)
1703:45	−13	−9	−15	−22	−16
1703:50	−17	−11	−19	−22	−17
1704:00	−16	−7	−13	−24	−15
1704:10	−15	−5	−11	−19	
1704:20	−11	−2	−12	−18	
1704:30	−16	−8	−18	−22	−20
1704:40	−15	−6	−15	−20	−21
1704:50		−17	−18		−22
1705:00	−13	−17	−21		−18
1705:10	−13	−9	−21	−24	−15
1705:20	−17	−17	−22		
1705:30	−16	−18	−22		
1705:40	−15	−14	−15	−20	−17
1705:50	−19	−14	−21	−24	−21
1706:00	−16	−11	−23		
1706:10		−15			
1706:20		−17			
1706:30	−16	−18			
1706:40	−16	−12			
1706:50	−18	−17	−21	−25	−16
1707:00	−20	−12	−18	−21	
1707:10	−15	−10	−15	−18	−16
1707:20	−19	−20	−17	−21	−20
1708:00	−19	−12	−20	−19	−14
1708:10	−13	−9	−19	−21	−15
1708:20	−13	−9	−19	−21	−15
1708:30	−13	−9	−17	−21	−16
1708:40	−13	−9	−16	−21	−15
1708:50	−20	−19	−21	−22	−24

([redacted]) The LOS results above showed item 1 above for the LOS case to be ≈ +10 dB or more, items 2 and 3 being about +3 dB for the LOS case. Other comments will be made about this later in the discussion section.

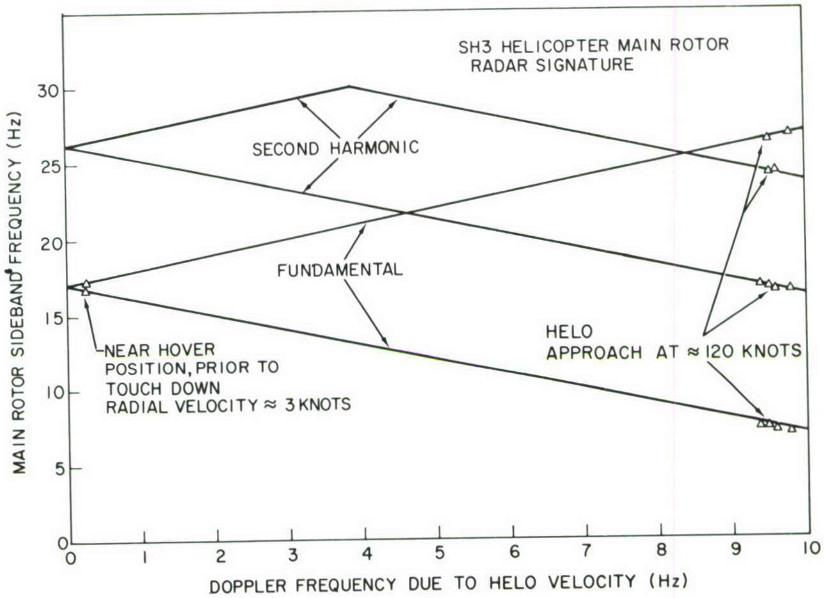
([redacted]) Figure 14 is a doppler-vs-range display record for the time 1711:05. In evidence are several aircraft above 25-Hz doppler at various ranges from 1536 to 2187 naut mi. Of particular significance is the "paired" echo centered on the range strobe at 2079 naut mi. The doppler strobe is aligned with the lower of the two video signals. These two signals are centered in doppler on 16.9 Hz, the blade rotation rate of the SH-3D helicopter. The split in the two signals represents a radial velocity imparted to the helicopter either by its own motion (nearly broadside) or by that of the *U.S.S. Independence*, if the helicopter had already landed. Other evidence indicates that the helicopter had not landed but that it was in an approach-to-land pattern and on a nearly tangential (broadside) path to the radar. Even though the fuselage echo at nearly 0 doppler is obscured by earth clutter, the first-order sidebands are clearly discernible. If the helicopter's motion had been precisely tangential to the radar beam direction, the split rotor signal would have collapsed to one video signal centered on 16.9 Hz.



([redacted]) Fig. 14—Doppler-vs-range display taken at 1711:05 GMT with SH-3D helicopter at 2079 naut mi. The doppler and range extents are as indicated.

([redacted]) The unique signal echoes received from the SH-3D prompt the suggestion that the helicopter (or some other set of rotating blades) could turn up on the flight deck and scatter back to the radar a singular 16.9-Hz component or a split echo (centered on 16.9 Hz) whose magnitude of split would convey the ship's radial velocity. The helicopter could be very useful indeed in OTH ship finding.

([redacted]) Figure 15 shows the expected doppler behavior of the fundamental (first order) and second harmonic (second order) of the SH-3D rotor modulations as a function of platform



([redacted]) Fig. 15—Expected doppler behavior of SH-3D helicopter rotor modulations as a function of the fuselage doppler (due to velocity) for a pulse-repetition frequency of 60 Hz. The ordinate is rotor sideband frequency; the abscissa is the fuselage doppler frequency.

radial velocity (converted to doppler in Hz for the given operating frequency) for the case of the approaching helicopter. The pulse repetition frequency for the observations of 23 September 1971 was 60 Hz. This results in an unambiguous doppler range of 30 Hz. Those components that increase sideband frequency as they depart the left axis (zero radial velocity) are the approach components, whereas those that decrease sideband frequency immediately as they move to the right of the zero-velocity axis are the recede components. It is noted that the second-order approach component becomes ambiguous at approximately 4 Hz on the abscissa.

([redacted]) The radar data points are indicated by triangles; these are grouped between 9 and 10 Hz on the abscissa and at a single point at a fraction of 1 Hz. For the helicopter doppler variation (due to radial velocity) between 9.4 Hz and 9.8 Hz, it can be seen that all components lie very close to the various expected values and that the sense of change in doppler of a sideband frequency is in the proper direction for changes in helicopter radial velocity.

DISCUSSION

([redacted]) That a fleet-deployed helicopter could be used as a range discriminant for the purposes of locating surface units, otherwise obscured by clutter, has been determined feasible on the basis of this report. Observations have confirmed the expected spectral behavior of the SH-3D main-rotor-blade echoes. The SH-3D has proved to be very visible at OTH ranges. Its unique signature, embodying the rotor doppler components, has permitted its differential separation from other aircraft.

(S) The relative amplitudes of the various spectral components appear to be ordered in a particular fashion, depending on whether the rotating blade structure is approaching the radar or receding. This is perhaps due to positional modification in the phase center of the echoing structure. The increase in second-order components in the case of the refracted observations may be due to polarization or angle-of-arrival effects. Other investigations should yield a more definitive dependence.

(S) For the surveillance observation of 23 September 1971, the flight of the SH-3D helicopter did in fact permit the location of the *U.S.S. Independence.*

(S) Consideration is being given to the development of a transponder capable of serving as a ship locator. The use of the helicopter for remote-position location certainly would not displace the use of this transponder when it becomes available, but in the present interim could provide such a capability.

FUTURE WORK

(S) The preceding reported observations are merely a first step in determining the reliability of helicopter signatures for remote surface-unit location. The total characterization of the SH-3D helicopter signature is far from complete. Other investigations are indicated, to permit a comprehensive definition, in the following areas:

- Examination of the compound echo to determine the degree of interaction of fuselage with rotor blades, if any.

- Scheduling of other line-of-sight observations with the SH-3D and other helicopters to examine rotor echo behavior under both horizontally and vertically polarized fields for different attitudes of the helicopter, such as approach, recede, climb, descent, and turn.

- Correlation of OTH observations of helicopter activity during transit of the *U.S.S. Independence* with her flight logs.

APPENDIX

(U) This appendix is an extraction from *Jane's Fighting Ships* (4) to show the increase in embarked helicopters with surface units of the U.S. Fleet. These helicopters are found on the following ship types: CVA, CVS, DD, DLG, CLG, DLGN, OE, amphibious assault, amphibious cargo, amphibious transport, ammunition, and combat store. Helicopters are also assigned to oilers and Coast Guard cutters. The helicopters perform many varied functions aboard ship, as indicated by the following incomplete list:

- All-weather search and rescue
- Antisubmarine warfare
- Plane guard duty during air operations
- Gunfire observation and target reporting
- Vertical replenishment

- Courier service, ship to ship and ship to land
- Casualty evacuation
- Personnel transfer
- Tactical air control
- Reconnaissance missions
- Wire laying, towing
- Logistic support

([redacted]) This appendix is only intended to provide an awareness of widespread use of helicopters with surface elements of the U.S. Fleet. As the ship-detection emphasis grows, the appendix material should provide valuable data as to whether helicopters are embarked on a particular ship.

(U) In the listing of the appendix, the word "target" means that a given ship or class of ships was observed to have a target (landing area for helicopters) amidship or at the stern, but no further information was available as to the particular helicopter type assigned to that ship or class of ships.

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APPENDIX (Unclassified)

U.S. NAVAL UNITS

Ship	Ship Type	Embarked Helicopter
Kitty Hawk CVA 63	Attack carrier	16 SH-3's, utility helicopter
Constellation CVA 64	Attack carrier	16 SH-3's, utility helicopter
America CVA 66	Attack carrier	16 SH-3's, utility helicopter
J. F. Kennedy CVA 67	Attack carrier	16 SH-3's, utility helicopter
Enterprise CVAN 65	Attack carrier	Utility helicopters
Forrestal CVA 59	Attack carrier	Utility helicopters
Saratoga CVA 60	Attack carrier	Utility helicopters
Ranger CVA 61	Attack carrier	Utility helicopters
Independence CVA 62	Attack carrier	Utility helicopters
Midway CVA 41	Attack carrier	Utility helicopters
Franklin D. Roosevelt CBA 42	Attack carrier	Utility helicopters
Coral Sea CVA 43	Attack carrier	Utility helicopters
Hancock CVA 19	Attack carrier	Utility helicopters
Oriskany CVA 34	Attack carrier	Utility helicopters
Intrepid CVS 11	ASW support carrier	16-18 SH-3 Sea Kings, utility helicopter
Ticonderoga CVS 14	ASW support carrier	16-18 SH-3 Sea Kings, utility helicopter
Lexington CVT 16	ASW support carrier	16-18 SH-3 Sea Kings, utility helicopter
Wasp CVS 18	ASW support carrier	16-18 SH-3 Sea Kings, utility helicopter
Albany CG 10	Guided missile cruiser	Utility helicopter
Chicago CG 11	Guided missile cruiser	Utility helicopter
Columbus CG 12	Guided missile cruiser	Utility helicopter
Long Beach CGN	Guided missile cruiser	Utility helicopter
Little Rock CLG 4	Guided missile light cruiser	Utility helicopter
Oklahoma City CLG 5	Guided missile light cruiser	Utility helicopter
Providence CLG 6	Guided missile light cruiser	Utility helicopter
Springfield CLG 7	Guided missile light cruiser	Utility helicopter
Truxtun DLGN 35	Guided missile frigate	Full helicopter support capability
Belknap DLG 26	Guided missile frigate	Full helicopter support capability
Josephus Daniels DLG 27	Guided missile frigate	Full helicopter support capability
Wainwright DLG 28	Guided missile frigate	Full helicopter support capability
Jouett DLG 29	Guided missile frigate	Full helicopter support capability
Horne DLG 30	Guided missile frigate	Full helicopter support capability
Sterett DLG 31	Guided missile frigate	Full helicopter support capability
William H. Standley DLG 32	Guided missile frigate	Full helicopter support capability
Fox DLG 33	Guided missile frigate	Full helicopter support capability
Biddle DLG 34	Guided missile frigate	Full helicopter support capability
Bainbridge DLGN 25	Guided missile frigate	Target
Leahy DLG 16	Guided missile frigate	Target
Harry E. Yarnell DLG 17	Guided missile frigate	Target
Worden DLG 18	Guided missile frigate	Target
Dale DLG 19	Guided missile frigate	Target
Richmond K. Turner DLG 20	Guided missile frigate	Target
Gridley DLG 21	Guided missile frigate	Target
England DLG 22	Guided missile frigate	Target
Halsey DLG 23	Guided missile frigate	Target
Reeves DLG 24	Guided missile frigate	Target

U.S. NAVAL UNITS—Continued

Ship	Ship Type	Embarked Helicopter
Farragut DLG 6	Guided missile frigate	Target
Luce DLG 7	Guided missile frigate	Target
MacDonough DLG 8	Guided missile frigate	Target
Coontz DLG 9	Guided missile frigate	Target
King DLG 10	Guided missile frigate	Target
Mahan DLG 11	Guided missile frigate	Target
Dahlgren DLG 12	Guided missile frigate	Target
William V. Pratt DLG 13	Guided missile frigate	Target
Dewey DLG 14	Guided missile frigate	Target
Preble DLG 15	Guided missile frigate	Target
Lloyd Thomas DD 764	Destroyer	Facilities for small helicopter
Keppler DD 765	Destroyer	Facilities for small helicopter
Harwood DD 861	Destroyer	Facilities for small helicopter
Carpenter DD 825	Destroyer	Facilities for small helicopter
Robert A. Owens DD 827	Destroyer	Facilities for small helicopter
Chevalier DD 805	Destroyer	Facilities for small helicopter
Benner DD 807	Destroyer	Facilities for small helicopter
Everett F. Larson DD 830	Destroyer	Facilities for small helicopter
Perkins DD 877	Destroyer	Facilities for small helicopter
Allen M. Sumner DD 692	Destroyer	Facilities for small helicopter
Ingraham DD 694	Destroyer	Facilities for small helicopter
Wallace L. Lind DD 703	Destroyer	Facilities for small helicopter
Hugh Purvis DD 709	Destroyer	Facilities for small helicopter
Laffey DD 724	Destroyer	Facilities for small helicopter
O'Brien DD 725	Destroyer	Facilities for small helicopter
Strong DD 758	Destroyer	Facilities for small helicopter
James C. Owens DD 776	Destroyer	Facilities for small helicopter
Brooke DEG 1	Guided missile escort	Facilities for small helicopter
Ramsey DEG 2	Guided missile escort	Facilities for small helicopter
Schofield DEG 3	Guided missile escort	Facilities for small helicopter
Talbot DEG 4	Guided missile escort	Facilities for small helicopter
Richard L. Page DEG 5	Guided missile escort	Facilities for small helicopter
Julius A. Furer DEG 6	Guided missile escort	Facilities for small helicopter
Knox DE 1052	Escort	Are programmed to receive Light Airborne Multi-Purpose System (LAMPS) helicopter to become operational in mid-1970's (2 helicopters per ship)
Roark DE 1053	Escort	
Gray DE 1054	Escort	
Hepburn DE 1055	Escort	
Connole DE 1056	Escort	"
Rathburne DE 1057	Escort	"
Meyerkord DE 1058	Escort	"
W. S. Sims DE 1059	Escort	"
Lang DE 1060	Escort	"
Patterson DE 1061	Escort	"
Whipple DE 1062	Escort	"
Reasoner DE 1063	Escort	"
Lockwood DE 1064	Escort	"
Marvin Shields DE 1066	Escort	"
Francis Hammond DE 1067	Escort	"
Vreeland DE 1068	Escort	"
Downes DE 1070	Escort	"
Badger DE 1071	Escort	"
Blakely DE 1072	Escort	"
Harold E. Holt DE 1074	Escort	"
Trippe DE 1075	Escort	"

U.S. NAVAL UNITS—Continued

Ship	Ship Type	Embarked Helicopter
Ouellet DE 1077	Escort	Are programmed to receive Light Airborne Multi-Purpose System (LAMPS) helicopter to become operational in mid-1970's (2 helicopters per ship)
Joseph Hewes DE 1078	Escort	
Bowen DE 1079	Escort	
Paul DE 1080	Escort	
Garcia DE 1040	Escort	Facilities for small helicopter
Bradley DE 1041	Escort	Facilities for small helicopter
Edward McDonnell DE 1043	Escort	Facilities for small helicopter
Brumby DE 1044	Escort	Facilities for small helicopter
Davidson DE 1045	Escort	Facilities for small helicopter
Voge DE 1047	Escort	Facilities for small helicopter
Sample DE 1048	Escort	Facilities for small helicopter
Koelsch DE 1049	Escort	Facilities for small helicopter
Albert David DE 1050	Escort	Facilities for small helicopter
O'Callahan DE 1051	Escort	Facilities for small helicopter
Bronstein DE 1037	Escort	Facilities for small helicopter
McCloy DE 1038	Escort	Facilities for small helicopter
John Willis DE 1027	Escort	Facilities for small helicopter
Van Voorhis DE 1028	Escort	Facilities for small helicopter
Hartley DE 1029	Escort	Facilities for small helicopter
Joseph K. Taussig DE 1030	Escort	Facilities for small helicopter
Blue Ridge LCC 19	Amphibious command	Utility helicopter carried
Mount Whitney LCC 20	Amphibious command	Utility helicopter carried
Eldorado LCC 11	Amphibious command	Utility helicopter carried
Iwo Jima LPH 2	Amphibious assault	20-24 medium (CH-46) helicopters
Okinawa LPH 3	Amphibious assault	4 heavy (CH-53) helicopters
Guadalcanal LPH 7	Amphibious assault	4 observation (HU-1) helicopters
Guam LPH 9	Amphibious assault	''
Tripoli LPH 10	Amphibious assault	''
New Orleans LPH 11	Amphibious assault	''
Inchon LPH 12	Amphibious assault	''
Charleston LKA 113	Amphibious cargo ship	Helicopter deck
Durham LKA 114	Amphibious cargo ship	Helicopter deck
Mobile LKA 115	Amphibious cargo ship	Helicopter deck
St. Louis LKA 116	Amphibious cargo ship	Helicopter deck
El Paso LKA 117	Amphibious cargo ship	Helicopter deck
Tulare LKA 112	Amphibious cargo ship	Helicopter landing platform
Paul Revere LPA 248	Amphibious transport	Helicopter landing platform
Francis Marion LPA 249	Amphibious transport	Helicopter landing platform
Austin LPD 4	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Ogden LPD 5	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Duluth LPD 6	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Cleveland LPD 7	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Dubuque LPD 8	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Denver LPD 9	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Juneau LPD 10	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Coronado LPD 11	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Shreveport LPD 12	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Nashville LPD 13	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Trenton LPD 14	Amphibious transport dock	6 UH-34 or CH-46 helicopters
Ponce LPD 15	Amphibious transport dock	6 UH-34 or CH-46 helicopters

U.S. NAVAL UNITS—Continued

Ship	Ship Type	Embarked Helicopter
Raleigh LPD 1	Amphibious transport dock	6 UH-34 or CH-46 helicopters. These ships are not normally assigned helicopters because they lack integral hangers and maintenance facilities. Amphibious assault ships would provide helicopters during an amphibious operation. The La Salle has successfully operated 6 SH-3A Sea King's for an extended period.
Vancouver LPD 2	Amphibious transport dock	
La Salle LPD 3	Amphibious transport dock	
Anchorage LDS 36	Dock landing ship	Helicopter platform aft
Portland LDS 37	Dock landing ship	Helicopter platform aft
Pensacola LSD 38	Dock landing ship	Helicopter platform aft
Thomaston LSD 28	Dock landing ship	Helicopter landing platform
Plymouth Rock LSD 29	Dock landing ship	Helicopter landing platform
Fort Snelling LSD 30	Dock landing ship	Helicopter landing platform
Point Defiance LSD 31	Dock landing ship	Helicopter landing platform
Spiegel Grove LSD 32	Dock landing ship	Helicopter landing platform
Alamo LSD 33	Dock landing ship	Helicopter landing platform
Hermitage LSD 34	Dock landing ship	Helicopter landing platform
Monticello LSD 35	Dock landing ship	Helicopter landing platform
MSS 1	Special minesweeper	Target
Kilauea AE 26	Special minesweeper	Normally assigned 2 UH-46 cargo helicopters
Butte AE 27	Special minesweeper	
Santa Barbara AE 28	Special minesweeper	"
Mount Hood AE 29	Special minesweeper	"
Suribachi AE 21	Ammunition	Helicopter platform
Mauna Kea AE 22	Ammunition	Helicopter platform
Nitro AE 23	Ammunition	Helicopter platform
Pyro AE 24	Ammunition	Helicopter platform
Haleakala AE 25	Ammunition	Helicopter platform
Vesuvius AE 15	Ammunition	Helicopter platform
Mount Katmai AE 16	Ammunition	Helicopter platform
Great Sitkin AE 17	Ammunition	Helicopter platform
Diamond Head AE 19	Ammunition	Helicopter platform
Arcturus AF 52	Store	Target
Rigel AF 58	Store	Helicopter platform
Vega AF 59	Store	Helicopter platform
Denebola AF 56	Store	Helicopter platform
Regulus AF 57	Store	Helicopter platform
Mars AFS 1	Combat store	Normally assigned 2 UH-46 helicopters
Sylvania AFS 2	Combat store	Normally assigned 2 UH-46 helicopters
Niagara Falls AFS 3	Combat store	Normally assigned 2 UH-46 helicopters
White Plains AFS 4	Combat store	Normally assigned 2 UH-46 helicopters
Concord AFS 5	Combat store	Normally assigned 2 UH-46 helicopters
San Diego AFS 6	Combat store	Normally assigned 2 UH-46 helicopters
Neosho AO 143	Oiler	Helicopter platform
Mississinewa AO 144	Oiler	Helicopter platform
Truckee AO 147	Oiler	Helicopter platform
Mispillion AO 105	Oiler	Helicopter platform
Navasota AO 106	Oiler	Helicopter platform

U.S. NAVAL UNITS—Continued

Ship	Ship Type	Embarked Helicopter
Passumpsic AO 107	Oiler	Helicopter platform
Pawcatuck AO 108	Oiler	Helicopter platform
Waccamaw OA 109	Oiler	Helicopter platform
Sacramento AOE 1	Fast combat support	Normally assigned 2 UH-46 helicopters
Camden AOE 2	Fast combat support	Normally assigned 2 UH-46 helicopters
Seattle AOE 3	Fast combat support	Normally assigned 2 UH-46 helicopters
Detroit AOE 4	Fast combat support	Normally assigned 2 UH-46 helicopters
Wichita AOR 1	Replenishment oiler	Normally assigned 2 UH-46 helicopters
Milwaukee AOR 2	Replenishment oiler	Normally assigned 2 UH-46 helicopters
Kansas AOR 3	Replenishment oiler	Normally assigned 2 UH-46 helicopters
Savannah AOR 4	Replenishment oiler	Normally assigned 2 UH-46 helicopters
Samuel Gompers AD 37	Destroyer tender	Target
Puget Sound AD 38	Destroyer tender	Target
Aeolus ARC 3	Cable ship	Helicopter platform
Thor ARC 4	Cable ship	Helicopter platform
Alatna T-AOG 81	Gasoline tanker	Helicopter flight deck
Chattahoochee T-AOG 82	Gasoline tanker	Helicopter flight deck
Gearing DD 710	Destroyer	Facilities for small helicopters
Wiltsie DD 716	Destroyer	Facilities for small helicopters
Theodore E. Chandler DD717	Destroyer	Facilities for small helicopters
Hamner DD 718	Destroyer	Facilities for small helicopters
William C. Lawe DD 763	Destroyer	Facilities for small helicopters
Rowan DD 782	Destroyer	Facilities for small helicopters
Gurke DD 783	Destroyer	Facilities for small helicopters
Henderson DD 785	Destroyer	Facilities for small helicopters
Richard B. Anderson DD 786	Destroyer	Facilities for small helicopters
James E. Kyes DD 787	Destroyer	Facilities for small helicopters
Hollister DD 788	Destroyer	Facilities for small helicopters
Eversole DD 789	Destroyer	Facilities for small helicopters
Shelton DD 790	Destroyer	Facilities for small helicopters
Johnston DD 821	Destroyer	Facilities for small helicopters
Robert H. McCard DD 822	Destroyer	Facilities for small helicopters
Agerholm DD 826	Destroyer	Facilities for small helicopters
George K. MacKenzie DD 836	Destroyer	Facilities for small helicopters
Sarsfield DD 837	Destroyer	Facilities for small helicopters
Power DD 839	Destroyer	Facilities for small helicopters
Glennon DD 840	Destroyer	Facilities for small helicopters
Noa DD 841	Destroyer	Facilities for small helicopters
Warrington DD 843	Destroyer	Facilities for small helicopters
Perry DD 844	Destroyer	Facilities for small helicopters
Bausell DD 845	Destroyer	Facilities for small helicopters
Ozbourn DD 846	Destroyer	Facilities for small helicopters
Richard E. Kraus DD 849	Destroyer	Facilities for small helicopters
Joseph P. Kennedy Jr. DD 850	Destroyer	Facilities for small helicopters
Rupertus DD 851	Destroyer	Facilities for small helicopters
Leonard F. Mason DD 852	Destroyer	Facilities for small helicopters
Charles H. Roan DD 853	Destroyer	Facilities for small helicopters
Vogelgesang DD 862	Destroyer	Facilities for small helicopters
Harold J. Ellison DD 864	Destroyer	Facilities for small helicopters
Charles R. Ware DD 865	Destroyer	Facilities for small helicopters
Cone DD 866	Destroyer	Facilities for small helicopters

U.S. NAVAL UNITS—Continued

Ship	Ship Type	Embarked Helicopter
Stribling DD 867	Destroyer	Facilities for small helicopters
Brownson DD 868	Destroyer	Facilities for small helicopters
Arnold J. Isbell DD 869	Destroyer	Facilities for small helicopters
Floyd B. Parks DD 884	Destroyer	Facilities for small helicopters
John J. Craig DD 885	Destroyer	Facilities for small helicopters
Orleck DD 886	Destroyer	Facilities for small helicopters
Brinkley Bass DD 887	Destroyer	Facilities for small helicopters
Meredith DD 890	Destroyer	Facilities for small helicopters
Epperson DD 719	Destroyer	Facilities for small helicopters
New DD 818	Destroyer	Facilities for small helicopters
Holder DD 819	Destroyer	Facilities for small helicopters
Rich DD 820	Destroyer	Facilities for small helicopters
Basilone DD 824	Destroyer	Facilities for small helicopters
Robert L. Wilson DD 847	Destroyer	Facilities for small helicopters
Damato DD 871	Destroyer	Facilities for small helicopters
Eugene A. Greene DD 711	Destroyer	Facilities for small helicopters
William R. Rush DD 714	Destroyer	Facilities for small helicopters
William M. Wood DD 715	Destroyer	Facilities for small helicopters
Southerland DD 743	Destroyer	Facilities for small helicopters
McKean DD 784	Destroyer	Facilities for small helicopters
Higbee DD 784	Destroyer	Facilities for small helicopters
Dennis J. Buckley DD 808	Destroyer	Facilities for small helicopters
Corry DD 817	Destroyer	Facilities for small helicopters
Myles C. Fox DD 829	Destroyer	Facilities for small helicopters
Hanson DD 832	Destroyer	Facilities for small helicopters
Herbert J. Thomas DD 833	Destroyer	Facilities for small helicopters
Charles P. Cecil DD 835	Destroyer	Facilities for small helicopters
Fiske DD 842	Destroyer	Facilities for small helicopters
Steinaker DD 863	Destroyer	Facilities for small helicopters
Hawkins DD 873	Destroyer	Facilities for small helicopters
Henry W. Tucker DD 875	Destroyer	Facilities for small helicopters
Rogers DD 876	Destroyer	Facilities for small helicopters
Vesole DD 878	Destroyer	Facilities for small helicopters
Leary DD 879	Destroyer	Facilities for small helicopters
Dyess DD 880	Destroyer	Facilities for small helicopters
Bordelon DD 881	Destroyer	Facilities for small helicopters
Furse DD 882	Destroyer	Facilities for small helicopters
Newman K. Perry DD 883	Destroyer	Facilities for small helicopters
Stickell DD 888	Destroyer	Facilities for small helicopters
O'Hare DD 889	Destroyer	Facilities for small helicopters

[redacted]

Security Classification

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13. ABSTRACT

([redacted]) Recent over-the-horizon (OTH) surveillance exercises conducted by the Naval Research Laboratory in cooperation with air and surface units of the U.S. Fleet have permitted the opportunity for detection and characterization of the rotor modulations of the SH-3D helicopter.

([redacted]) The uniqueness of the radar signature of the SH-3D rotor blade affords adequate discrimination in an environment of multiple conventional aircraft. Such echoes have been obtained from the SH-3D at line-of-sight ranges and at approximately 870 and 2070 naut mi from the radar.

([redacted]) Though no extensive detection statistic has yet been accumulated, use of a ship's own helicopter for locating the ship's position within the OTH-sensor envelope has been tentatively demonstrated, as disclosed in this report.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radar Target signatures Signal processing Target identification						

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(PAGE 2)

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